

# IN DEFENSE OF SCULPINS

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Freshwater sculpins (genus *Cottus*) are common inhabitants of trout and salmon streams throughout the Northern hemisphere. As their large mouths attest, they are voracious predators, particularly on benthic invertebrates. They are often abundant in riffles where salmon and trout are spawning and in areas where salmonid fry are abundant. These observations have led many fisheries biologists to conclude that sculpins may have a detrimental impact on salmonid populations through predation on the eggs and fry and through competition for benthic invertebrates (Hartley 1948; Müller 1952; Shapovalov and Taft 1952; Hunter 1959; Reed 1967; Brocksen, Davis, and Warren 1968; Andreasson 1971; Patten 1971, 1975; Clary 1972; Mason and Machidori 1976). Although other studies have indicated that sculpins probably have little impact on salmonid populations (Surber 1920; Ricker 1941; Patten 1962; Straskraba 1966; Petrosky and Waters 1975; Li and Moyle 1976) or may have a beneficial effect (Dietsch 1950; Heard 1965; Ebert and Summerfelt 1969), the matter is far from settled. If sculpins do, in fact, have a significant negative impact on our ever-declining wild populations of salmon and trout, then some form of sculpin control may be desirable. The purpose of this paper, therefore, is to examine the evidence available on sculpin predation on salmonids and on sculpin-salmonid competition, to see if sculpin control might be a viable management tool.

## PREDATION

The evidence for sculpin predation on the fry and eggs of salmonids comes from four types of studies: (1) studies on the feeding habits of natural populations of sculpins; (2) studies of the stomach contents of sculpins in cages or traps containing salmonid fry in streams; (3) observations of sculpin behavior in association with spawning salmon; and (4) laboratory experiments.

When the stomach contents of sculpins from trout streams are examined, trout eggs and fry are usually rare or absent. In 15 studies involving 11 species of sculpins in undisturbed streams, only 45 out of 7785 sculpin stomachs (0.6%) contained either salmonid eggs (10) or fry (35) (Hartley 1948; Dietsch 1950; Dineen 1951; Zarbock 1951; Bailey 1952; Patten 1962;

Straskraba et al. 1966; Mann and Orr 1969; Andreasson 1971; Pasch and Lyford 1972; Antonelli, Nussbaum, and Smith 1972; Novak and Estes 1974; Mason and Machidori 1975; Petrosky and Waters 1975; Li and Moyle 1976). While the different species of sculpins may differ in their abilities to capture salmonid eggs and fry (Patten 1962, 1971), studies of sculpins confined in traps or cages with salmonid fry indicate that probably all species will take them if given an opportunity. Thus, Shapovalov and Taft (1954) found that prickly sculpin (*C. asper*) and coastrange sculpin (*C. aleuticus*) will gorge themselves on salmon fry when trapped with them in fry traps, where no other food is available. Similarly, Clary (1972) demonstrated that slimy sculpin (*C. cognatus*) readily took brown trout (*Salmo trutta*) fry that were introduced into two small stream "exclosures" containing the sculpins. Clary also found that sculpins in the stream itself were attracted to and consumed the easily available sac-fry escaping from the exclosures and from nearby exposed Vibert boxes.

Even under artificial conditions, the effectiveness of sculpin predation depends on a number of factors, including size of the sculpins (Clary 1972), environmental conditions such as temperature and light level, size of the salmonid fry, and behavioral characteristics of each salmonid species (Patten 1975). Studies by Patten (1975) in stream aquaria indicate that pink salmon (*Oncorhynchus gorbuscha*) and chum salmon (*O. keta*) fry are highly vulnerable to torrent sculpin (*C. rhotheus*) predation; chinook salmon (*O. tshawytscha*) and coho salmon (*O. kisutch*) have a comparatively low vulnerability to the predation, while sockeye salmon (*O. nerka*) and rainbow trout (*S. gairdneri*) are intermediate in their vulnerability.

The high vulnerability of pink and chum salmon fry to sculpin predation, combined with their concentration in the lower reaches of the spawning streams, may lead to high levels of sculpin predation on them in some situations (Hunter 1959). Using estimates of predation based on the stomach contents of prickly and coastrange sculpins, juvenile coho salmon, and other fishes caught in fry traps, Hunter calculated that over a 10-year period predators consumed an average of 45 percent of the emerging fry. Thirty-one percent of this predation (i.e., 14 percent of the fry) was taken by sculpins. Since the fry emerged mostly during a 35-day period, and since the sculpins apparently moved up into the stream from the estuary in response to salmon spawning and fry emergence, the actual percent of the fry consumed by the sculpins (and other predators) depended on the total number of fry emerging, which in turn was related to the number of spawning adults (Hunter 1959). The lowest annual sculpin predation rate that can be calculated from Hunter's data is 10 percent, the highest 28 percent, although it is likely that these rates are somewhat high since they are based on fry consumption by sculpins in fry traps. Sculpin predation rates on salmonid fry may also be high when large numbers of hatchery-produced fry are dumped into a stream containing large sculpin populations (Patten 1971).

Observations of sculpin behavior in association with salmon

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spawning indicates that they may take considerable numbers of eggs, since sculpins typically position themselves immediately downstream from an active salmon redd (Reed 1967). The eggs thus taken are either those that did not get buried following the spawning act or those from previous spawns that are dug up by the salmon during redd construction. Such eggs are eaten not only by sculpins, but by other fishes (Reed 1967) and by other predators, particularly gulls (Moyle 1966). The survival of these eggs is thus in doubt, with or without sculpins. The sculpins and other fishes below the redds are probably also feeding on the benthic invertebrates released into the water by the spawning salmon (Hildebrand 1971). When sculpins are taken in areas where trout are spawning, eggs are generally much less abundant than benthic invertebrates in the stomachs (Surber 1920; Dineen 1951). In fact, more eggs can usually be found in the stomachs of the spawning trout than in the sculpins (Dineen 1951; Dietsch 1950).

Once the eggs are buried, they are relatively unavailable to sculpins because sculpins seem to require moving prey (Novak and Estes 1974; Li and Moyle 1976) and because it is unlikely sculpins can penetrate normal stream gravels to a great enough depth. However, sculpins are capable of penetrating beds of large, uniform-sized gravel, typical of artificial spawning channels, and of capturing alevins (Phillips and Claire 1966).

It is evident that sculpins are effective predators on the eggs and fry of salmonids either under artificial conditions, such as in fry traps or man-made spawning channels, or in situations where small fry are very concentrated. In most trout and salmon streams, the latter situations seldom occur. Even in areas where fry are concentrated, sculpin predation may not be a problem if the sculpins do not have other sources of food close by, upon which they can feed when the fry are not there. In pink and chum salmon spawning streams, such as the one studied by Hunter (1959), the sculpins live most of the year in the estuaries and are in the streams mostly during the one to three months the fry are emerging and the salmon spawning. In a situation such as this (as Hunter's 1959 data indicate), the number of sculpins is likely to be determined more by the ability of the estuaries to support sculpins than by the number of salmon fry produced. As a consequence, significant reductions in the number of spawning salmon caused by overfishing is likely to aggravate the effects of sculpin predation greatly. When salmonid production in a stream is enhanced through plants of fry, losses of the planted fry can be greatly reduced by providing proper diets and exercise for the fry so they become vigorous swimmers, and by releasing the

fry in large numbers (Patten 1971). In major salmon spawning areas that are distant from potential sculpin refuges, spawning salmon may actually reduce the carrying capacity of the area for sculpins because their spawning activity has long-term negative effects on the populations of benthic invertebrates sculpins depend on most of the year (Hildebrand 1971).

## COMPETITION

Competition between sculpins and salmonids is frequently inferred from the apparent overlap in their diets (e.g., Hartley 1948; Andreasson 1971; Mason and Machidori 1976), although there are surprisingly few studies actually comparing the diets in one stream. One way of looking at the overlap in diets is to calculate, from the data available in the literature, the index of overlap of Pianka (1973):

$$\alpha_{ij} = \frac{\sum P_{ih} P_{jh}}{(\sum P_{ih}^2)(\sum P_{jh}^2)}$$

where  $P_{ih}$  is the proportion of an item in the diet of species  $i$  and  $P_{jh}$  is the proportion of an item in the diet of species  $j$ . The value of  $\alpha$  ranges from 0, where there is no overlap in diet, to 1.00 when there is complete overlap. When the  $\alpha$  values are calculated for 9 different salmonid-sculpin species pairs, the results are quite variable (Table 1), with 5 of the 9 showing relatively little overlap.

The  $\alpha$  values, like the conclusions of the individuals performing the actual studies, seem to be greatly influenced by 3 nonbiological factors: the sample sizes, the method of recording the feeding habits, and the precision of identification of the food organisms. The sample sizes of trout are usually small when compared to the samples of sculpin, which fact probably increases the variability of the  $\alpha$  values. When the relative importance of food organisms is determined by volume, the  $\alpha$  values tend to be low, while those based on number are variable but include all the highest values (Table 1). Another problem with the comparisons of stomach contents is that in most of the studies the identification of most food organisms is down only to the order level, when it is quite likely that different species within an order differ in their relative vulnerability to sculpin and trout predation. It is worth noting that the three high  $\alpha$  values in Table 1 were all calculated from studies in which the stomach contents were identified down only to the order level.

Besides the sampling problems, there are three interrelated assumptions associated with inferring competition from food

Table 1. Index of dietary (niche) overlap ( $\alpha$ ) between nine sculpin-salmonid pairs.

Sculpin Species	Sculpin Sample Size N	Salmonid Species	Salmonid Sample Size N	Method	Number Food Categories	$\alpha$ Index	Source
<i>Cottus bairdi</i>	97	<i>Salmo clarkii</i>	71	volume	19	0.18	Zarbock, 1951
<i>Cottus poecilopsis</i>	93	<i>Salmo trutta</i>	168	number	19	0.25	Straskraba, et al., 1966
<i>Cottus pitensis</i>	317	<i>Salmo gairdneri</i>	13	volume	15	0.31	Li and Moyle, 1976
<i>Cottus aleuticus</i>	30	<i>Oncorhynchus kisutch</i>	30	number	15	0.34	Mason and Machidori, 1975
<i>Cottus beldingi</i>	404	<i>Salvelinus fontinalis</i>	36	volume	16	0.38	Dietsch, 1950
<i>Cottus gobio</i>	210	<i>Salmo trutta</i>	308	number	28	0.57	Andreasson, 1971
<i>Cottus bairdi</i>	170	<i>Salmo trutta</i>	213	number	17	0.82	Dineen, 1951
<i>Cottus bairdi</i>	213	<i>Salvelinus fontinalis</i>	27	number	15	0.84	Dineen, 1951
<i>Cottus aleuticus</i>	30	<i>Salmo clarkii</i>	30	number	12	0.84	Mason and Machidori, 1975

overlap studies that have to be satisfied if competition is to be demonstrated: (1) that the food items are equally available to each species; (2) that the food is, in fact, limiting the salmonid populations; and (3) that the contested food, if it is limiting, is in short supply. If competition for food between sculpins and salmonids occurs, it would most likely be over the benthic invertebrates, such as baetid mayfly larvae, that are abundant in the drift. Most salmonids take such organisms mainly as drift, since it is probably more efficient for them to do so than to forage for them on the bottom (Waters 1972); while the sculpins take such organisms on the bottom, since they are not morphologically suited for capturing drifting organisms. One other indication of the differences in feeding methods between salmonids and sculpins is that salmonids tend to have peaks of feeding around dusk and dawn, when drift is abundant; while sculpins seem to be more or less continuous feeders (Moyle 1976; Li and Moyle 1976). Thus it is difficult to judge whether or not invertebrates that drift are equally vulnerable to sculpins and salmonids, since they usually take invertebrates at different times and places. In addition, if the hypothesis that drifting invertebrates represent surplus production (Waters 1972) is correct, then it is particularly unlikely that competition for the invertebrates is occurring.

For most salmonids, because they hold feeding territories and are often members of dominance hierarchies (Jenkins 1969), space rather than food is probably the main factor limiting population size, although feeding territories do tend to be smaller in more productive streams (Chapman and Bjornn 1969). However, there do appear to be some salmonid populations that are limited by the available food supply at certain times of the year, and so the possibility of competition for that limited food supply has to be considered (Mason and Machidori 1976). Unfortunately, most studies comparing salmonid and sculpin feeding habits gave no indication of the abundance of the food or space requirements of the fish. The reason for this, of course, is that both are very hard to demonstrate. One way around this problem, however, is to determine the biomass of salmonids in comparable situations with and without sculpins. If salmonid biomass is considerably higher in the absence of sculpins, then it is probable that the sculpins are limiting salmonid production through competition for some resource.

The main study using the biomass limitation approach that has been cited as evidence of sculpin-salmonid competition (e.g. Andreasson 1971; Petrosky and Waters 1975; Mason and Machidori 1976) is that of Brocksen, Warren, and Davis (1968). This study was carried out in six laboratory streams in which four factors were varied: the amount of light entering the system, and the combinations of cutthroat trout (*S. clarkii*), reticulate sculpins (*C. perplexus*) and predacious stoneflies (*Acroneuria* spp.). In only two of the streams could the results be applied to the evaluation of trout-sculpin competition, one containing only trout, the other both sculpins and trout. Three of the other streams contained both stoneflies and sculpins and the fourth contained only trout under a different light regime. In the two streams that were comparable, the trout had a total energy utilization of 11.1 kcal/m<sup>2</sup> (production of 0.5 kcal/m<sup>2</sup>) in the stream in which they were the only fish; while in the stream with sculpins the trout were able to utilize only 6.9 kcal/m<sup>2</sup>. While these figures have been used to indicate that sculpins can limit trout production, their validity for this can be questioned because gross plant production in the sculpin stream was only 66 percent that of the gross plant production in the trout-only stream. Since in both streams the trout were feeding on herbivorous insects, it is not surprising their production was less in the stream with less

primary production. Indeed, if trout production in the trout-only stream is reduced by 34 percent, only about 7.7 kcal/m<sup>2</sup> (production of 1.5 kcal/m<sup>2</sup>) would be utilized by the trout, a figure not much higher than the one from the trout-sculpin stream. It should also be noted that total fish production from the sculpin-trout stream was only 0.7 kcal/m<sup>2</sup>, an indication that the system may not have been a healthy one. Other limitations of this study are the lack of replication of the above experiment, the small number (3) of trout used in each stream, and the general problems associated with trying to apply results from simplified laboratory situations to the more complex situations found in nature. Indeed, the one study that might have produced some indication of a negative relationship between sculpin and trout production in a stream found none (Petrosky and Waters 1975).

Overall, the case for competition between sculpins and salmonids is very weak, being based largely on inferences from data limited in both quantity and quality. In most cases, the data can be used to argue equally well either for or against competition. Competition between sculpins and salmonids may exist, but it has yet to be conclusively demonstrated. Even if it does exist, it seems unlikely that it would have a significant long-term effect on salmonid populations except under unusual circumstances. Since sculpins and salmonids apparently evolved together in coldwater streams, it is likely that if a food item does become in short supply, prey switching by one or both species is likely to occur after perhaps a transitory period of competition. In most salmonid streams, competition between morphologically similar species of salmonids would seem to have a higher probability than competition between the morphologically dissimilar sculpins and salmonids.

## CONCLUSIONS

The limited evidence available indicates that sculpins can severely limit salmonid populations through either predation or competition only under exceptional or artificial conditions. Probably the most severe damage by sculpins takes place in situations where man has already badly damaged the salmonid populations through over-exploitation or environmental disturbances. Obviously, more definitive work needs to be done on sculpin-salmonid interactions in streams, particularly in natural or near-natural situations, before sculpins can be condemned as being responsible for salmonid declines. Work also needs to be done on the positive aspects of sculpin-salmonid interactions. Sculpins are commonly important prey of lake-dwelling salmonids (e.g. Heard 1965; Ebert and Summerfelt 1969) and occasionally in streams (Dietsch 1950). Dietsch (1950) thought that sculpin in Sagehen Creek, California, serve as a "buffer" prey species for brook trout by reducing brook trout predation on their own young. It is also possible that sculpin predation on predacious stoneflies may increase the supply of drifting herbivorous insects for trout and perhaps reduce stonefly predation on eggs and young of trout. Overall, control of sculpins may improve salmonid production in some situations, mostly artificial, but it is unlikely that any form of sculpin control will have much effect (except possibly negative) on salmonid populations for which there is well-managed fishery.

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#### OCEAN FLOOR HOT SPRINGS

Scientists have begun diving to the bottom of the Pacific Ocean in a 22-foot three-man sub to explore the vents in the sea floor through which metal-bearing hot waters flow. The findings are expected to help scientists understand the formation of metal-rich deep sea sediments, the history of the chemistry of sea water, and the transfer of heat from the earth's interior into the oceans. Most of the geothermal energy reaching the earth's surface is carried by mid-ocean ridge hot springs. Dr. John B. Corliss, Assistant Professor of Oceanography at Oregon State University, is project coordinator.